

L-BAND AND SHF MULTIPLE ACCESS SCHEMES FOR THE MSAT SYSTEM

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ABSTRACT

The first generation of the Canadian Mobile Satellite (MSAT) system, planned to be operational in the early 1990s, will provide voice and data services to land, aeronautical, and maritime mobile terminals within the Canadian land mass and its territorial waters. The system will be managed by a centralized Demand Assignment Multiple Access (DAMA) control system. Users will request a communication channel by communicating with the DAMA Control System (DCS) via the appropriate signalling channels.

Several access techniques for both L-band and SHF signalling channels have been investigated. For the L-band, Slotted Aloha (SA) and Reservation Aloha (RA), combined with a token scheme, are discussed here. The results of Telesat studies to date indicate that SA, when combined with token scheme, provides the most efficient access and resource management tool in a mobile propagation environment.

For SHF signalling channels, slim-TDMA and SA have been considered as the most suitable candidate schemes. In view of the operational environment of the SHF links, provision of a very short channel access delay and a relatively high packet success rate are highly desirable. Studies carried out generally favour slim-TDMA as the most suitable approach for SHF signalling channels.

1.0 INTRODUCTION

Communication Services within urban centres and surrounding areas are readily available using terrestrial and fixed satellite systems. Recently, the demand for reliable nationwide mobile communications in rural areas has significantly increased. This paper briefly introduces Telesat's baseline networking concept and control architecture as foreseen for provision of Mobile Satellite (MSAT) services. The emphasis is placed on the various multiple access schemes contemplated for interconnecting the network elements as are presently defined. These schemes are tailored to satisfy the projected Canadian needs, while being in harmony with the present state of the relevant technology.

2.0 BACKGROUND

MSAT is intended to provide cost effective, spectrally efficient services for voice and data communications across Canada. There will be a large number of mobile users, each characterized by bursty traffic and a low activity factor; therefore, the system's available spectrum will best be utilized by a Demand Assignment Multiple Access (DAMA) control system.

The DAMA Control System (DCS) will be responsible for network supervision and providing interconnection among various network elements such as mobile terminals, base stations, and gateways. It will also be communicating with the network management system, responsible for long-term resource planning, overall supervision and maintenance of the system.

The major categories of service that have been identified to date as potential applications for MSAT upon its introduction are: a) Mobile Radio Service (MRS) targetting mobile communities of various sizes consisting of one or more base stations (dispatch centres) and a number of MRS terminals; b) Mobile Telephone Service (MTS) destined for mobile users requiring Public Switched Telephone Network (PSTN) interconnectivity, via gateway stations; c) MSAT Data Services (MDS) for users with one-way or two-way data transmission requirements; and d) MSAT Aeronautical and Marine Services.

To provide these services, two distinct types of channels are required within the pool of MSAT channels:

- Communication channels used by all the users to transmit and receive voice or data, and
- Signalling channels used by all the users as well as the DCS to transmit and receive call requests/responses, commands, etc.

The signalling among the DCS, gateways, and base stations will be over the SHF-SHF links (or in some cases they may interface using terrestrial links). For mobile terminals, signalling will be via L-band-SHF links to the DCS.

It should be noted that packet switched data communications would be provided by data hubs using slim-TDMA channels. These channels will be assigned dynamically to data hubs from the pool of MSAT channels; however, circuit switched data communications would be treated the same as the voice channels. The study of packet switched data services will not be addressed here.

3.0 ACCESS SCHEMES

Different access techniques for both L-band and SHF signalling channels have been investigated. The request and assignment channels will form the major interface between the user and the MSAT DCS. As a result, it will be critical that their operation satisfies the criteria imposed by both the user and the system requirements. In comparing various access schemes, the degree with which the following design objectives are met by each approach should be carefully quantified:

- Minimizing the number of signalling channels;

- Minimizing the call set-up/take-down delay;
- Ensuring stability of the channels; and
- Minimizing mobile terminal complexity.

Furthermore, there are two more important resource management issues to be assessed before defining selection criteria.

First, it is highly desirable to assign a communication channel when the called party goes off hook, as opposed to assigning a channel upon a call request and waiting for the called party's response. Such a deferred communications channel assignment approach will result in significant savings in the scarce satellite power and bandwidth.

Second, the size of the packets on the signalling channels has a direct relationship with the number of signalling channels required to support the traffic generated by the MSAT users. A packet consists of information bits, overhead bits, and guard time. Presently, a packet size of 150 bits[1] appears to be sufficient for MSAT system.

3.1 L-Band Signalling Channels

For the L-band signalling channels, Slotted Aloha (SA) and Reservation Aloha (RA), combined with a token scheme, have been investigated and their performances are described here. The L-band signalling channels are divided into three categories:

- Request channels will be used by mobile terminals to communicate with the DCS, and will be in SA or RA mode.
- Token channels will be used by mobile terminals to transmit on-hook, off-hook, and acknowledgments to messages received from the DCS.
- Assignment channels will be used by the DCS to respond to mobile requests and issue commands to mobiles.

The signalling channels will be operating at 2400 bps using Differential Minimum Shift Keying (DMSK) modulation.

The channels in SA mode will be used solely for transmission of call request, log-on, log-off, and ranging messages. The log-on/log-off message transmissions are expected to occur during the non-busy-hour period. The 2400 bps channel is divided into 16 slots of 150-bits long for these messages.

The RA scheme is based on a random access scheme (SA) to reserve a particular slot for transmitting a call request packet. The Reservation Request Channel (RRC) is divided into two different types of slots: First, large slots (150 bits) used for transmission of call request, log-on, log-off, and ranging messages; second, mini-slots (15 bits) used to transmit a four-bit token in SA mode to reserve one of the large slots for transmitting call request and log-off messages. Every large slot is followed by a group of ten mini-slots.

The downlink part of RRC is used to transmit the reservation response messages from the DCS to the mobiles.

For the token scheme, the 2400 bps channel is also divided into 15-bit slots. During the call set-up procedure (after reception of call request) the DCS will designate one slot to the L-band called-party. This slot will be used by the mobile to transmit four-bit tokens signifying on-hook, off-hook, and acknowledgement to messages received from the DCS.

3.2 Link Availability of L-Band Signalling Channels

The performance of signalling channels will be significantly dependant on the propagation effects, which in turn depends on the elevation angle to the satellite as well as the amount and type of blockage and shadowing predominate in the service area. The baseline system design assumes that mobiles would be limited to a service area defined by a minimum elevation angle of 20° to the satellite. It is to be noted that a very large proportion of the potential mobile users in Canada fall within this limit. Application of measured fade statistics for areas in which woodlands constitute up to 35% of the land area[2] indicated that a 99% availability for the signalling channels is attainable. The probability of packet loss on forward and reverse links for mobiles is calculated to be limited to 11% and 11.6%, respectively. The probability of token misdetection on the reverse link is expected to be 0.3%[1].

3.3 Comparison of Access Schemes

For brevity, the channel performance and delay analysis for both access schemes would not be presented here in detail. Interested readers may refer to Reference 1 for a detailed performance analysis of these schemes. Figures 1 and 2 show channel performance versus delay curves for both SA and RA schemes combined with a token scheme. In Figure 1, the percentage of packets transmitted successfully after m transmissions on the request channel is plotted against the call set-up delay. Note that call set-up delay accounts for the time from transmission of first indication of call request from mobile until successful reception of ringback message (acknowledgement) by the mobile from the DCS. Table 1 further compares the performance of the two schemes:

Table 1 Comparison of SA and RA

	Slotted aloha		Reservation aloha	
	Success rate	Delay (sec)	Success rate	Delay (sec)
First try	69.3	0.92	76.3	1.96
Second try	17.6	1.99	1.0	2.72
Third try	7.5	3.06	14.5	3.97
Fourth try	3.25	4.13	5.4	5.89
Total	98.95%		97.2%	

In Figure 2, the channel throughput (in terms of number of packets) is plotted against the average delay on the channel. As shown, the delay experienced by RA is usually twice as much as that of SA, since the process involves transmission of two messages from the mobile to the DCS (one token, one message).

It is interesting to note that increasing the number of signalling channels in SA scheme improves the performance of the network, while its effect on RA is insignificant. SA is more adaptable to environments with various propagation characteristics,

while RA is more susceptible to high packet error rates on the link. In addition, RA uses one more L-band downlink channel than SA for transmitting the reservation response messages. One of the advantages of RA scheme is its capability of handling up to seven calls/sec/channel compared to SA handling only four calls/sec/channel, ensuring channel stability as shown in Figure 2.

The above study clearly shows that, under the assumptions used, SA outperforms the RA access scheme.

3.4 SHF Signalling Channels

The baseline traffic model developed for the first generation MSAT indicates that the Canadian mobile satellite network will consist of about 150 base stations and four gateways, each generating varying amounts of SHF traffic[3]. It is assumed that every station would transmit a message every 2.3 seconds[3]. With the main objective to minimize the channel access delay, the following access schemes have been considered:

- Random access, and
- Fixed assignment.

The only candidate considered for random access is SA due to its higher performance compared to pure Aloha and its faster response with respect to RA. Typically, the channel throughput for an SA channel would be approximately 15% for a reasonable degree of packet collisions and packet delay. As a result, the number of required channels would be 30 channels. One of the major drawbacks of this access scheme is that collision of messages such as off-hook, on-hook, and acknowledgments could result in long call processing delays and chaos in signalling channels.

For fixed assignments, an FDMA system with dedicated channels, or a TDMA system with permanently assigned time slots, have been investigated. Due to the requirement for transmitting on average one message every 2.3 seconds, an FDMA system would not be practical. Even though there would be no channel access delay for this scheme, the channel throughput would be very low (in the order of $1/(16 \times 2.3) = 2.7\%$ assuming a 2400 bps data rate and 150-bit packets).

In the case of a TDMA system with 2.3 second long frames, and every station being assigned to a particular time slot in a channel, the channel utilization will be very high, requiring only five signalling channels. However, in such a system, the average channel access delay will be excessively high (about 1.15 seconds long). For the purpose of analysis, an average channel access time of 300 ms is assumed to be reasonable. To accommodate such channel access delays, the frame size could be reduced to 600 ms resulting in approximately sixteen signalling channels. Note that channel utilization will be 24.5% assuming a 2400 bps data rate. The channel efficiency would be increased to 26% if the transmission rate is increased to 4800 bps. The number of required channels in this case will be half of the previous case, so the SHF spectrum requirement will remain the same.

The assignment channels are similar to broadcast channels. The DCS would be the only transmitter on these channels. The SHF stations will monitor them continuously while they are logged on to the system.

Telesat's studies indicate that the TDMA access scheme with a 600 ms frame size can satisfy the Canadian system and user requirements. The channel performance will be the highest and the average channel access time will be 300 ms. It should be pointed out that the data transmission rate would not influence the signalling channels' performance significantly; however, the packet transmission time and packet processing delay will be reduced.

Note that base stations and gateway stations will share the signalling channels. A dynamic signalling channel assignment scheme should be implemented to provide flexibility in the system operation.

The most important phenomenon affecting the SHF link performances is the attenuation of the signal by rain in the earth-to-space paths. Telesat's studies indicate that a one-way propagation availability better than 99.99% of time can be achieved for most Canadian users. This availability could be further improved if uplink power control is used at the central control station site.

4.0 CALL SET-UP PROCEDURE

Figure 3 provides a time diagram describing how the various access schemes would be used in setting up/taking down a call. As shown, a base station initiates a call by transmitting a call request to the DCS. The mobile party would be informed via L-band assignment channels. The ringing message would be acknowledged by an Ack token on the token channel. A second token would indicate an off-hook. At this point in time, a voice channel would be assigned to both parties.

For call take-down, one of the parties goes on-hook which causes transmission of a tone over the voice channel to the other party. The terminal then informs the DCS. In the case of mobile users, a token would be sent over the a token channel. The DCS sends call termination messages to both parties and reclaims the voice channel.

5.0 CONCLUSION

Candidate multiple access schemes for L-band and SHF signalling channels in the Canadian MSAT system have been described here. It was shown that the most appropriate channel access scheme for the mobile terminals would be SA combined with a token scheme using L-band channels. Furthermore, slim-TDMA with short frames was shown to be the superior approach for the SHF signalling channels.

REFERENCES

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- [2] Butterworth, J. "Propagation Measurements for Land-Mobile Satellite Systems at 1542 MHz", Department of Communications Report, Ottawa, Canada, August 1984.
- [3] "MSAT System and Service Definition", Telesat Canada, prepared for Department of Communications, Ottawa, Canada, October 1987.

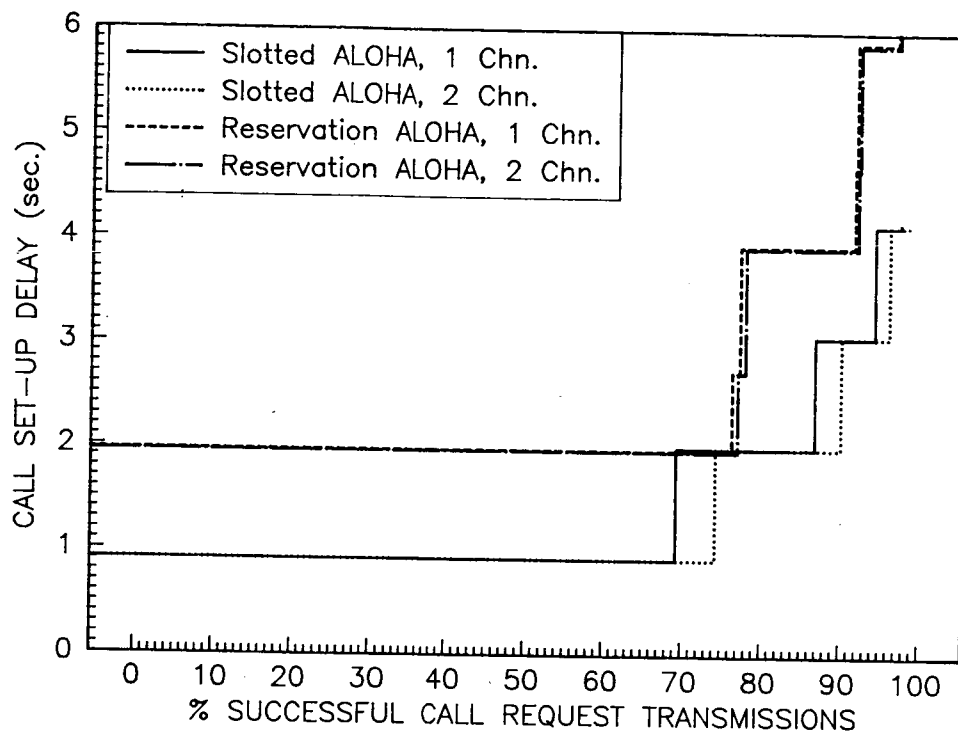


Fig 1. Comparison of slotted aloha and reservation aloha access schemes based on call set-up delay

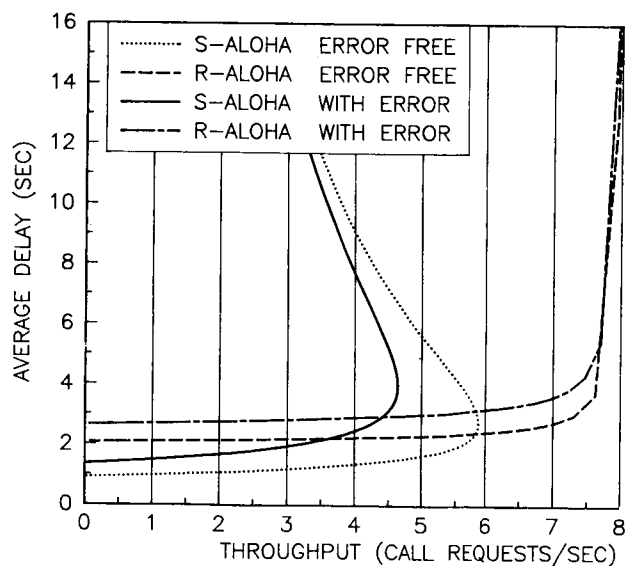


Fig. 2. Total capacity of slotted aloha and reservation aloha schemes versus average delay

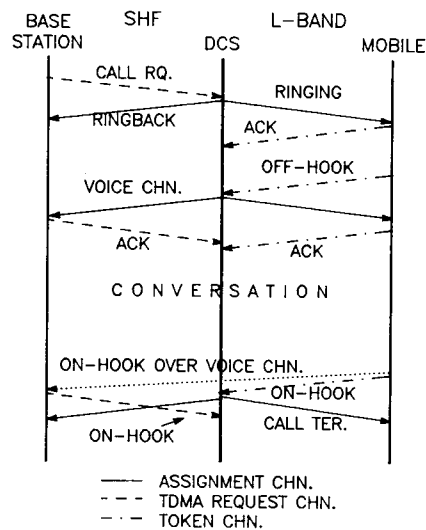


Fig 3. Call set-up/take-down procedure for an MRS call